USAARL Report No. 2018-02

Review of U.S. Army Aviation Accident Reports: Prevalence of Environmental Stressors and Medical Conditions

By Kathryn Feltman[1,2], Amanda Kelley[1], Ian Curry[1], David Boudreaux[1], Lana Milam[1], Colby Mathews[1,2], Deborah Russell[1,3]

[1]U.S. Army Aeromedical Research Laboratory
[2]Oak Ridge Institute for Science and Education
[3]Wyle-CAS Group

United States Army Aeromedical Research Laboratory

Aircrew Health and Performance Division

October 2017

Approved for public release; distribution unlimited.

Human Subject Use

In the conduct of research involving human subjects, the investigator(s) adhered to the policies regarding the protection of human subjects as prescribed by Department of Defense Instruction 3216.02 (Protection of Human Subjects and Adherence to Ethical Standards in DoD-Supported Research) dated 8 November 2011.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
18-10-2017	Final	01-05-2016 - 30-04-2017

4. TITLE AND SUBTITLE Review of U.S. Army Aviation Accident Reports: Prevalence of Environmental Stressors and Medical Conditions	**5a. CONTRACT NUMBER** N/A **5b. GRANT NUMBER** N/A **5c. PROGRAM ELEMENT NUMBER** N/A
6. AUTHOR(S) Feltman, Kathryn A. Kelley, Amanda M. Curry, Ian P. Boudreaux, David A. Milam, Lana Mathews, Colby Russell, Deborah	**5d. PROJECT NUMBER** N/A **5e. TASK NUMBER** N/A **5f. WORK UNIT NUMBER** N/A
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Aeromedical Research Laboratory P.O. Box 620577 Fort Rucker, AL 36362	**8. PERFORMING ORGANIZATION REPORT NUMBER** USAARL 2018-02
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Medical Research and Materiel Command 504 Scott Street Fort Detrick, MD 21702-5012	**10. SPONSOR/MONITOR'S ACRONYM(S)** USAMRMC **11. SPONSOR/MONITOR'S REPORT NUMBER(S)** N/A

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES
Oak Ridge Institute for Science and Education; Wyle-CAS Group

14. ABSTRACT
Human error and factors contributing to diminished human performance in the cockpit impact the safety of aircrew and mission success. A number medical factors and environmental stressors are known to impact aircrew performance, but what is unknown is the extent to which these factors are cited in accident reports. The objective was to review aviation accident reports and determine the frequency with which environmental and health factors are cited/included in these documents. The U.S. Army Combat Readiness Center's Risk Management Information System (de-identified and available using their online system) was the source of this information. The results support degraded visual environments as a top priority for aviation safety.

15. SUBJECT TERMS
Army aviation, helicopter, environmental stress, accident, mishap

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Loraine St. Onge, PhD
UNCLAS	UNCLAS	UNCLAS	SAR	16	**19b. TELEPHONE NUMBER** *(Include area code)* 334-255-6906

This page is intentionally blank.

Acknowledgements

The authors would like to express their sincere gratitude to the U.S. Army Combat Readiness Center for providing access to the Risk Management Information System.

This research was supported in part by appointments to the Postgraduate and Knowledge Preservation Programs at the U.S. Army Aeromedical Research Laboratory administered by the Oak Ridge Institute for Science and Education through an interagency agreement between the U.S. Department of Energy and the U.S. Army Medical Research and Materiel Command.

This page is intentionally blank.

Table of Contents

List of Tables

Introduction

A variety of factors can contribute to diminished human performance in the cockpit and impact the safety of aircrew and mission success. A number of medical factors and environmental stressors are known to impact aircrew performance, but what is unknown is the extent to which these factors are cited in recent U.S. Army aviation accident reports. The goal of this project was to review aviation accident reports for manned aircraft and determine the frequency with which medical and environmental factors are cited/included in these documents. The U.S. Army Combat Readiness Center's Risk Management Information System (RMIS) (de-identified and accessible using the online system) was the source of this information.

Background

The influence of environmental stressors on aircrew health, performance, and safety has been studied in the fields of aviation and human factors for many years. In fact, a recent article provides a brief description of military aviation psychology and cites the first study to have occurred in 1919 (Staal, 2014). Significant contributions made to expand the knowledge base over the past nine decades on these topics provide a strong foundation for continuing development of countermeasures in a dynamic landscape and evaluating the degree to which moderating and mediating conditions contribute to decreases in operational effectiveness and, in some cases, adverse outcomes. In order to inform future research efforts, this study reviewed available Class A and B U.S. Army aviation accident reports for the presence of operational and environmental stressors as well as medical conditions of the crew members and operators.

Class A mishaps are defined as:

> An Army accident in which the resulting total cost of property damage is $2,000,000 or more; an Army aircraft or missile is destroyed, missing, or abandoned; or an injury and/or occupational illness results in a fatality or permanent total disability.

Class B mishaps are defined as:

> An Army accident in which the resulting total cost of property damage is $500,000 or more, but less than $2,000,000; an injury and/or occupational illness results in permanent partial disability, or when 3 or more personnel are hospitalized as inpatients as the result of a single occurrence (U. S. Army Combat Readiness Center).

Stress can be defined as a stimulus or condition that requires an individual to adapt. In other words, the individual must adjust or attempt to maintain performance or function in the presence of such a stimulus. This adaptation may be expressed physiologically or behaviorally. When an individual is unable to adequately adapt to the presence of the stimulus or condition, decrements may follow in which the individual is unable to maintain behavioral response capacity and/or physiological response capacity (Hancock & Szalma, 2008). Army aircrew face a number of stressors during operations including spatial disorientation, hypoxia, altitude, thermal stress, noise, vibration, psychological stress, cognitive workload, and fatigue. In most scenarios, an aircrew member is able to adequately adapt to the presence of one or multiples of these stressors; however, accident reports that include information related to one of the previously mentioned stressors may be indicative of a situation in which the aircrew were unable to adapt to the stressor. Determining the frequency in which these stressors are included in accident reports

may allow for the identification of which stressors to focus research efforts on to develop a clearer understanding of the impact of these stressors on performance.

Method and Materials

Data source

All U.S. Army Class A and B aviation accident reports from Fiscal Year 2011 (beginning 1 October 2010) through Fiscal Year 2015 (ending 30 September 2015) were retrieved for review. A total of 215 reports were retrieved from the U.S. Army Combat Readiness Center's RMIS and reviewed. Of the 215 reports retrieved, 82 were unmanned aerial systems accidents, and were excluded from the current analyses, leaving 133 reports to review. Reports in this system do not include any personally identifiable information.

Procedure

All reports were reviewed and entries were organized in a database. Missing data elements were coded as "not available (NA)" and data elements not disclosed in the report were coded as "not disclosed (ND)." Each report was reviewed with respect to the likelihood of the presence of a medical condition in crew member or operator as well as an operational stressor including environmental conditions, hypoxia symptoms, spatial disorientation, and fatigue. Narratives included in the report were reviewed for any terminology related to an aforementioned stressor or medical condition. Table 1 presents the identified operational stressor with the keywords extracted from the narratives within the reports and extracted data elements that were used to determine possible presence of associated medical condition or operational stressor.

Table 1. Extracted data elements and stressor definitions.

Stressor	**Narrative Keywords**	**Data Elements**			
Fatigue	Sleep, deprivation, tired, fatigue, rest	Hours slept (last 24 hrs)	Hours worked (last 24 hrs)	Hours flown (last 24 hrs)	Period of Day/Time
Environmental	Visual, weather-related, fog, dust	NVS used	Environmental (e.g., meteorological conditions)	Accident Cause Environmental	
Medical	Any medical condition or symptom				
Spatial Disorientation	SD related symptoms; reference to SD; failure to scan instruments; reference to orientation	Environmental (e.g., meteorological conditions)			

Hypoxia Symptoms	Hypoxia-related symptoms including loss of consciousness, breathlessness, hyperventilating, fatigue; reference to altitude				
Additional data elements extracted for descriptive purposes		Classification	Total Fatalities	Period of Day/Time	
		Num. aircraft involved	Total Disabling Injuries	Type event1	Type event2
		Aircraft type	Total Non-disabling Injures	Accident Cause Human Error (yes/no)	Type Accident Cause Environmental (yes/no)event3
		Aircraft category	Total Damage Cost	Accident Cause Materiel failure (yes/no)	Standards failure
		Individual failure	Support failure	Training failure	Leader failure

Note. Additional data elements extracted (e.g., *moon above horizon* and *moon visible*) are not listed given that data were missing or not reported for approximately 90% of the reports.

Quality Control and Statistical Analysis Approach

Data entry accuracy for the extracted information from the reviewed reports into the study database was assessed using a 10% sample. Statistical analyses were performed using the statistical software package Statistical Package for the Social Sciences (SPSS) release 19.0.0. Frequencies and descriptive statistics were calculated for the extracted data elements. Narrative descriptions provided in the reports were reviewed for trends.

Results

Of the 133 total reports retrieved, 74 were Class A and 59 were Class B. The total cost of damages across all incidents was $660,507,228 (data missing from 2 reports) and a total of 54 lives were lost (Table 2). With respect to aircraft type, 126 involved rotary-wing aircraft, and 6 involved fixed-wing aircraft (see Table 3 for airframe data; note that airframe type was not reported for one case). Of the incidents, 124 were during flight, 8 were flight related, and 1 was with the aircraft on the ground. Time of day was split between night and day with 62 occurring at night (1 report indicated not using night vision systems [NVS] when the circumstances of the flight would have warranted use); and 68 during the day (1 reported as occurring at dawn). The majority of the reports involved 1 aircraft (n = 122) and 9 involved two aircraft (note that 2 reports indicated no aircraft involved and were unique circumstances). Of those who reported

whether the incident occurred on- or off-post, 62 were off-post and 45 were on-post. Seventy incidents were reported as off-airfield and 35 were on-airfield.

Table 2. Total cost and injuries by classification.

	Frequency – Class A	Frequency – Class B
N	74	59
Total Cost	$611,345,963	$49,161,265
Total Fatalities	54	0
Total Disabling Injuries	41	3
Total Non-Disabling Injuries	45	11

Table 3. Airframe frequencies by classification.

Airframe	Frequency – Class A	Frequency – Class B	Accident Rate per 100,000 flying hours‡
MH-60	2	8	13.98
MD-530	1	0	10.65
HH-60	3	6	8.01
MI-8	0	1	5.65
MH-47	2	1	4.82
CH-47	10	7	4.38
AH-64	18	12	3.26
OH-58	12	5	2.08
UH-60	19	15	1.98
TH-67	0	2	0.51
C-130†	2	0	*
EO-5C	1	0	*
KA-300	1	1	*
UH-72	1	0	*
UV-20	1	0	*
Not reported manned airframe	1	0	NA

Note: *Data unavailable; †C-130s are not Army aircraft, but were included in two reports as they were involved in accidents with other Army aircraft; ‡accident rate per 100,000 flying hours was obtained through the U.S. Army Combat Readiness Center.

The reports include event types, in which the accident reviewers select up to three events which are identified by the investigators as characterizing the accident, with the first event type listed identified as the best event descriptor of the accident (Headquarters Department of the Army, 2015).With respect to event types and cited failures, only three reports cited “human factor” as the primary event type, and an additional three cited “human factor” as the secondary event type. Events were grouped, where possible, by technical, human or other catastrophic failure. Technical failures included landing gear collapse/retraction, uncommand control input, electrical system, hydraulic system, flight control, mast bumping, engine failure, blade flapping, fuel starvation, landing gear/arresting hook, and power train. Human failures included rotor/prop wash, engine overspeed, tree strike, wire strike, rescue operations, object strike, air to ground collision. Catastrophic failures included fire and/or explosion on ground and inflight breakup. Note, the releasable information within the report does not include accident cause factors, thus event types are reported and interpreted here as significant events that likely contributed to the accident. See Table 4 for further frequency information regarding event type.

The following definitions are used by the U.S. Army Combat Readiness Center (2015) for identifying the different human failure types: 1) training failure is defined as “when training is incorrect, incomplete or insufficient for an individual to perform a task to standard;” 2) standards failure is defined as “when standards do not exist or they are unclear, impractical, or inadequate. Failure to follow an established standard does not constitute a standards failure;” 3) leader failure is defined as “when leaders fail to monitor mission execution and planning, correct inappropriate behavior, take appropriate action or emphasize correct procedures that allowed subordinates to commit task errors or results in a materiel failure; 4) individual failure is defined as “when the individual knows the standard and is trained to standard but elected not to follow the standard;” 5) support failure is defined as “when the type, amount, capabilities, condition of the support is insufficient to correctly perform the mission” (pp. 3-10 – 3-11). Of the 40 human failures cited, three were training, three standards, five leader, 27 individual, and two support.

Table 4. Primary event types by classification

Primary*	**Class A Manned systems**	**Class B Manned systems**
Technical Failure	8	9
Human Failure	16	23
Other collision	13	9
Collision with ground/water	10	1
Hard landing	6	7
Multiple aircraft event	3	1
Flight related	2	3

Rotor/propellers	4	0
Dynamic rollover	1	3
Precautionary /Forced landing	1	0
Not reported	0	0
Mid-air collision	2	0
Catastrophic Failure	2	0
Equipment loss/damaged	1	1
Instrument meteorological	1	0
Engine overtorque/overload	1	0
Excessive yaw/spin	1	0
Fratricide	1	0
Aircraft ground accident	1	0
Tail boom strike	0	1
Rotor Overspeed	0	1

Discussion

Potential Stressors and Medical Conditions

Medical Conditions and Hypoxic Symptoms. No reports contained any information indicative of medical conditions or hypoxic symptoms.

Fatigue. Out of the 133 accident reports analyzed, 37 cases (approximately 28%) were identified with fatigue as potentially present based on interpretation of the narrative keywords and extracted data elements. The criteria for determining if fatigue was possibly present were based on a number of factors such as time of mishap (occurring between 2200 and 0600), number of hours slept by individual on flight controls (≤6 hr), and the number of hours worked (≥10 hr). This presented a number of limitations to the analysis of fatigue as possibly present in the dataset. Principally, the hours slept by individuals are self-reported or obtained from scheduling records. This leaves significant potential for inaccurate data being reported, thus the numbers presented here should be interpreted with caution.

The number of mishaps occurring at night (26) was higher than those during the day (11). A majority (21) of the night mishaps occurred between 2200 and 0600 with another two of the remaining daytime mishaps taking place before 1000. This indicates more than half of the accidents where pilot fatigue potentially occurred were during hours of the circadian rhythm when sleep drive is highest (Fuller, Gooley, & Saper, 2006). An interesting subset of these numbers is that 26 (70%) of the mishaps occurred OCONUS (Iraq or Afghanistan). This may provide some evidence that the sleeping environment in a deployed setting is not conducive for recuperative rest. If this is the case that would mean additional mishaps not included in this subgroup could be a result of fatigue-induced human error. Literature has shown repeated bouts of restricted or disruptive sleep can produce performance decrements such as reduced cognitive performance, loss of attention, decreased reaction time, and memory impairments (e.g., Lim & Dinges, 2008, attention/reaction time; Van Dongen, Maislin, Mullington, & Dinges, 2003, cognitive performance; Stickgold, 2005, memory).

Within the subset of 37 cases, 26 (70%) provided information for the pilot on flight controls. A relatively small number (5, 14%) of pilots on flight controls reported sleeping less than seven hours in 24 hr preceding the mishap. As mentioned previously, this seems surprising and is likely underreported given that recent polls of Americans revealed the average American receives approximately 6.8 hours of sleep per night (Jones, 2013) without the added stresses of sleeping in an operational environment. Conversely, 24 (65%) of those pilots worked at least 10 hours at the time of the mishap. The large percentage of individuals who are reported to have worked longer shifts may suggest a possible connection between the number of hours worked and the risk level of being involved in an aviation mishap. Although it is not possible to determine the exact relationship of hours worked and likelihood of an aviation mishap from this sample of accident reports, previous studies have identified that the likelihood of accidents in various occupational settings tend to increase in an exponential fashion with the number of hours on shift (e.g., Folkard & Tucker, 2003; Harrington, 2001). Additionally, it would be beneficial to differentiate between task-related fatigue, which could be presumed from number of hours worked, and sleep-related fatigue, which could be inferred from hours of sleep reported. Such a differentiation would allow for a more complete depiction of potential causal factors to accidents, as both task-related and sleep-related fatigue have been shown to negatively affect performance (e.g., Lim & Dinges, 2008; Van der Linden & Eling, 2006). While these reports do not provide sufficient data to make definitive conclusions regarding task-induced or sleep-related fatigue, it indicates a greater need to study the impacts of extended operations on operator performance and mishap risk in a more detailed and objective manner.

The impact of understanding the role fatigue plays in mishaps is important on many levels. Within this analysis, 15 fatalities and 16 total disabilities may have resulted from fatigue-related aviation mishaps. This also resulted in a total of $309 million in damages, which averages to about $7.7 million per mishap. Although the total number of fatalities and injuries may not be as high as other units in the Army, aviation mishaps account for a devastating financial and operational cost to the Army.

Spatial disorientation. Of the reviewed 133 reports, 27 were found to be possibly spatial-disorientation-related accidents. The mishaps occurring at night involved the use of NVS and typically involved brown-out conditions. The mishaps that occurred during the day also involved brown-out conditions. Brown-out occurs when dust or sand is stirred up by the

helicopter's rotor downwash, thus resulting in difficulties seeing outside the aircraft by creating a degraded visual environment (DVE). Brown-out conditions and other factors, such as severe weather, may have caused the pilots to experience SD. Spatial disorientation may have led to loss of proper control of the aircraft, damage to the aircraft itself, and death or injury to the crew members. Another frequently cited factor with respect to SD was "rising terrain in the environment," which was cited in several of the narratives within the reviewed accident reports. This can refer to an actual rise in terrain such as an unseen ridgeline or more rarely to the rising terrain visual illusion that can occur when flying with distorted ambient vision (Previc, 2004). Rising terrain in the environment occurs as a pilot misjudges the terrain elevation by misperceiving the size of objects on the ground, such as vegetation, which can result in the pilot's inability to correctly perceive a change in terrain levels. Although other illusions may have contributed to some of the accidents that occurred within the reviewed reports, rising terrain was the most frequently cited within the narratives.

Environmental factors. The accidents that reported as having environmental conditions as a possible factor included reports of wind, dust, brownout, and meteorological conditions, which can each create a DVE. The report form also includes a location for reporting environmental conditions at the time of the accident. Within the accidents reviewed, 52 reports identified visual meteorological conditions and one instrument meteorological conditions at the time of the accident, while the remaining accidents did not report this information. Additionally, approximately half of the accidents reported with environmental conditions as a possible factor occurred during nighttime operations. Of the accidents that occurred during nighttime operations, all but one manned aircraft flight reported the use of NVS during the flight. The majority of environmental information obtained from the accident reports was identified in the narrative summary reports of the accidents, which included notation of the following: use of NVS, occurrence of dust conditions and/or mention of brownout, wind conditions, and lack of visual references.

Limitations and future studies

The findings in this report are limited given the constraints associated with reviewing only the publicly available accident reports and not the full investigation results. In particular, a large amount of information is not releasable for publication in the database system for whatever reason or circumstance. For this type of review and summary, that information is simply not available.

Conclusions and Recommendations

A number of conclusions can be drawn from the data presented in this study regarding both the continuing threats to aviation and the need for adjustments to the level of detailed information that should be included in the investigation of mishaps and the subsequent report.

The stand-out results of the study are that DVEs remain a consistent and troubling top priority for aviation safety and accident prevention in rotary-wing operations, as identified in several, although by no means all, of the reports involving SD and environmental factors. Another finding arising from the data is that the report coding of accidents involving DVE, SD, and flight into terrain need to be examined to ensure consistency. Previous studies (Curry &

McGhee, 2007) focusing on SD accidents using the same data resource found that the recorded primary event type can vary significantly in very similar accident scenarios leading to the conclusion that the investigations and reports would benefit from tighter delineation of coding.

The reported incidence of fatigue as a possible causal factor in a significant number of the reported mishaps is at odds with the amount of sleep that the aviators/operators claimed to have had in the period before the incident. The hours of work reported would seem to be a more reliable indication of possible fatigue and are objective rather than the self-reported sleep data. Additional information reported in regards to both the hours worked and the type of work being done leading up to the accident would be useful in determining whether task- or sleep-related fatigue factors were involved. A more accurate method of recording actual sleep prior to incidents would be beneficial to further identify potential fatigue sources. This could be accomplished through activity monitors worn by aircrew, this monitoring might now be regarded as more acceptable by the soldier whilst on operations given the increased use of personal activity monitors in general use.

After reviewing the accident reports, the following are recommendations to improve the information gathered in those reports in order to allow more detailed analysis and meaningful conclusions to improve flight safety and operational capability:

- Training for more consistent reporting of accidents where SD, DVE, and flight into terrain may be causal factors.
- Recording additional information in regards to hours worked, such as the type of work performed, the time of day the work occurred, and whether the hours of work included the timing of the accident.
- Consider the incorporation of more accurate methods of monitoring number of hours slept, such as a wrist-worn activity monitor.

This page is intentionally blank.

References

Agius, R. M., Lloyd, M. H., Campbell, S., Hutchison, P., Seaton, A., & Soutar, C. A. (1994). Questionnaire for the identification of back pain for epidemiological purposes. *Occupational and Environmental Medicine, 51*, 756-760.

Curry, I. P., & McGhee J. S. (2007). Spatial disorientation as a cause of mishaps in combat helicopter operations . *Aviation, Space, and Environmental Medicine, 78*(3) 307.Folkard, S., & Tucker, P. (2003). Shift work, safety and productivity. *Occupational Medicine, 53*(2), 95-101.

Fuller, P. M., Gooley, J. J., & Saper, C. B. (2006). Neurobiology of the sleep-wake cycle: Sleep architecture, circadian regulation, and regulatory feedback. *Journal of Biological Rhythms*, *21*(6), 482-493.

Harrington, J. M. (2001). Health effects of shift work and extended hours of work. *Occupational and Environmental Medicine*, *58*(1), 68-72.

Hancock, P. A., & Szalma, J. L. (2008). Stress and performance. In P. A. Hancock & J. L. Szalma (Eds.), *Performance under stress* (pp. 1-18). Burlington, VA: Ashgate.

Headquarters Department of the Army (2015). *Army accident investigations and reporting* (DA PAM 385-40).

Jones, J. M. (2013, December 19). In U.S., 40% get less than recommended amount of sleep. *Gallup.* Retrieved from http://www.gallup.com/poll/166553/less-recommended-amount-sleep.aspx

Lim, J., & Dinges, D. F. (2008). Sleep deprivation and vigilant attention. Annals of the New York Academy of Sciences, *1129*(1), 305-322.

Previc, F. H. (2004). Visual illusions in flight. In F. H. Previc & W. R. Ercoline (Eds.). *Spatial disorientation in aviation* (pp. 283-317). Reston, VA: American Institue of Aeronautics and Astronautics, Inc.

Staal, M. A. (2014). A descriptive history of military aviation psychology. The Military Psychologist, doi: http://www.apadivisions.org/division-19/publications/newsletters/military/2014/04/aviation-psychology.aspx

Stickgold, R. (2005). Sleep-dependent memory consolidation. *Nature, 437*(7093), 1272-1278.

U.S. Army Combat Readiness Center (2015). *Accident Investigator's Handbook.*

U.S. Army Combat Readiness Center (2016). *Abbreviated Aviation Accident Report Use and Preparation Guide*.

Van der Linden, D., & Eling, P. (2006). Mental fatigue disturbs local processing more than global processing. *Psychological Research, 70* (5), 395-402.

Van Dongen, H. P., Maislin, G., Mullington, J. M., & Dinges, D. F. (2003). The cumulative cost of additional wakefulness: Dose-response effects on neurobehavioral functions and sleep physiology from chronic sleep restriction and total sleep deprivation. *Sleep, 26*(2), 117-126.

Department of the Army
U.S. Army Aeromedical Research Laboratory
Fort Rucker, Alabama, 36362-0577
www.usaarl.army.mil

U.S. Army Medical Research and Materiel Command